Hydrometrics, Inc.

2727 Airport Road • Helena, Montana 59601 • (406) 443-4150 • FAX (406) 443-4155

February 11, 1993

Scott Brown
U.S. Environmental Protection Agency
301 S. Park Federal Building
Box 10096
Helena, Montana 59626

RE: Lower Lake Sediment Leachate Impact Calculations

Dear Scott:

This letter provides calculations to estimate the impact to groundwater and surface water as a result of the marsh deposits that will remain in Lower Lake after removal of process and treatment sludges. As we discussed in our meeting last week, theoretical impacts of constituents remaining in marsh deposits can be calculated using available data collected during the RI and from the additional work conducted as part of the Lower Lake RD/RA efforts.

Leachate analyses of marsh deposits for arsenic using Method 1312 appears to be comparable to EP Toxicity analysis from the upper portion of marsh deposits collected during the RI (see Table 1 and Table 2 attached). The average of the Method 1312 analyses for arsenic was 0.46 as compared to 0.35 and 0.37 using the EP Toxicity test. A direct comparison of 1312 and EP Toxicity test results of Lower Lake upper marsh deposits suggests that in some circumstances EP Toxicity may be more aggressive for arsenic than 1312 (see Table 3 versus Table 2).

Review of RI EP Toxicity data from Lower Lake bottom sediments shows the strata below the uppermost (2 feet) marsh deposits generally had arsenic concentrations less than or near MCLs (see Table 1). Assuming the marsh deposits, including the uppermost sediments, contribute test leachate concentrations on a continuous basis (a very conservative assumption), theoretical groundwater and surface water loading can be calculated.

Groundwater flow and Lower Lake leakage were calculated using loading calculations for groundwater and Prickly Pear Creek during the Process Ponds RI (see Figure 3-3 attached). Groundwater flow down-gradient of Lower Lake was calculated using a form of the Darcy Flow Equation:

$$Q = T\ I\ L$$

where:

Q = groundwater flow (gpd)

T = shallow aquifer transmissivity in gpd/ft

I = gradient ft/ft

L = width of aquifer flow corridor in ft.

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For calculation purposes, groundwater flow down-gradient of Lower Lake was divided into two flow corridors. Groundwater flow was calculated as follows:

Corridor 1 $Q = T\ I\ L$

where: T = 8055 gpd/ft (Monitoring well DH-4)

$I = 0.02$

L = 500 ft

Q = 80,550 gpd or 56 gpm

Corridor 2 $Q = T\ I\ L$

where: T = 3575 gpd/ft (Monitoring wells DH-5 and DH-29)

$I = 0.03$

L = 750 ft

Q = 80,437 gpd or 55 gpm

Assuming Lower Lake is the source of elevated concentrations of arsenic in well DH-4 and in Prickly Pear Creek, an approximation of seepage to groundwater and surface water was made using the general loading calculation:

$$L_a + L_L = L_b$$

where: L_a = Arsenic load in groundwater or surface water up-gradient or above Lower Lake

L_L = Arsenic load in water seeping from Lower Lake to groundwater or surface water

L_b = Arsenic load in groundwater or surface water down-gradient or areally below Lower Lake.

Given: $L = FC$, the above equation can also be written as:

$$F_aC_a + F_LC_L = F_bC_b$$

where: F = Flow in gpm

C = Concentration of dissolved arsenic in mg/l.

In the Process Ponds RI, a solution for F_L was calculated for both groundwater and surface water with F_L being the hypothetical quantity of seepage from Lower Lake. Seepage from Lower Lake to groundwater was calculated as follows:

$$F_aC_a + F_LC_L = F_bC_b$$

where: F_a = 111 gpm (the sum of corridors 1 and 2)

C_a = 0.014 mg/l (up-gradient concentration from well DH-3)

C_L = 20 mg/l (concentration of Lower Lake)

F_b = 111 gpm

C_b = 4 mg/l (down-gradient concentration from well DH-4)

F_L is calculated to be 22 gpm.

Seepage to Prickly Pear Creek can also be calculated:

$$F_aC_a + F_LC_L = F_bC_b$$

where: F_a = 16,128 gpm (measured flow of 36 cfs)

C_a = 0.009 mg/l (up-stream dissolved concentration, PPC-3)

C_L = 20 mg/l (concentration of Lower Lake)

F_b = 16,128 gpm (downstream flow 36 cfs)

C_b = 0.02 mg/l (down-stream concentration PPC-33A)

F_L is calculated to be 9 gpm.

Using the calculated flow of 22 gpm to groundwater, the average permeability of strata underlying Lower Lake can be back calculated using the following formula modified from Walton (1970):

$$Q_L = \frac{P' \, Dh \, A_L}{M'}$$

where: Q_L = seepage through underlying strata in gpd

P' = vertical permeability of underlying strata

M' = thickness of underlying strata below the pond and above the saturated gravels.

A_L = area of strata underlying the lake through which seepage occurs

Dh = difference in head between the pond surface and groundwater level observed in well DH-4

Vertical permeability is calculated:

Q_L = 31,680 gpd

M′ = 13 feet (measured average from cross-section)

A_L = 304,920 ft^2 (7 acres of Lower Lake)

Dh = 12.09 feet

P′ = 0.1117 gpd/ft^2 (or 5.27×10^{-6} cm/sec)

Assuming an average of 2 feet of process sludge, and 1 foot of marsh deposits (for a total of 3 feet) would be removed from Lower Lake, and assuming average permeability remains the same, leakage from the pond following dredging is calculated as follows:

$$Q_L = \frac{0.117 * 12.09 * 304{,}920}{10} = 41{,}184 \text{ gpd or } 28.6 \text{ gpm.}$$

Assuming the EP Toxicity leachate data (Table 1) for LH-2 is representative of leachate from sediments remaining in the pond, theoretical groundwater concentrations can be calculated using the loading calculation:

$$F_aC_a + F_LC_L = F_bC_b$$

where: F_a = 111 gpm

C_a = 0.014 mg/l (up-gradient concentration from well DH-3)

F_L = 28.6 gpm.

C_L = 0.09 mg/l (the arithmetic averages of EP Toxicity concentrations in LH-2)
F_b = 111 gpm

C_b, the calculated down-gradient concentration at well DH-4 = 0.037 mg/l)

Theoretical concentrations in Prickly Pear Creek can also be calculated:

where: F_a = 16,128 gpm

C_a = 0.009 mg/l

F_L = 18 gpm (since some sediment is removed, a factor of 2 times the calculated leakage rate was assumed)

C_L = 0.09 mg/l (the arithmetic averages of EP tox concentrations in LH-2)

F_b = 16,128 gpm

C_b, the calculated concentration in Prickly Pear Creek = 0.0094 mg/l.

Based on this exercise, using calculated concentrations from EP Toxicity leachate results and system flow estimates, groundwater concentration increases would be measurable but less than MCLs and Prickly Pear Creek concentration increases can be calculated but would not be measurable.

It should be recognized that laboratory leachate results are greater than actual groundwater or surface water quality impacts. Laboratory leachate results are the result of rigorous test procedures that include grinding, agitation and acid leaching; actions which would not occur in undisturbed sediments left in Lower Lake. Grinding and agitation increase available surface area for leachate reactions to occur. It addition because of the alkaline (generally pH 8 or above) nature of waters in the area, including Lower Lake, Upper Lake, Prickly Pear Creek and groundwater, the acidic environment simulated in the laboratory is not likely to occur in Lower Lake.

The above groundwater and surface water concentration estimates are conservative for several additional reasons including:

- EP Toxicity leach rates are assumed to be continuous, a condition that would not likely occur in situ under present pH and redox conditions.

- Attenuation mechanisms including sorbsion and chemical coprecipitation are not accounted for in the above calculations. Data collected during the Comprehensive RI showed these mechanisms are significant factors in attenuation of arsenic migration.

- The primary source of groundwater and surface water arsenic is the concentration of water in Lower Lake itself. This is apparent from the correlation of groundwater quality in DH-4 with improving water quality in Lower Lake. Data in the RI shows that groundwater arsenic in DH-4 was originally measured to be as high as 11 mg/l.

This measurement correlated in time with Lower Lake water quality of about 80 mg/l. In 1988, groundwater arsenic concentrations in DH-4 were approximately 4 mg/l, which compares to a reduced arsenic concentration in Lower Lake of about 20 mg/l. Recent data show improvement in Lower Lake water quality to about 12 mg/l arsenic (based on summer 1991 results) which corresponds to a groundwater arsenic concentration of about 2 mg/l in well DH-4. As a result, it is expected water quality in Lower Lake will be the primary factor in influencing groundwater and surface water quality. The contribution from sediments is expected to be minimal by comparison.

The above calculations are not intended to be a prediction of actual concentrations and it is expected the contributions from sediments remaining after dredging would be less than calculated. However, even with the conservative assumptions used above, calculated groundwater and surface water concentrations would meet post-remediation targets.

If you have questions concerning the above, please call me.

Sincerely,

Robert J. Miller

Robert J. Miller
Hydrogeologist

/RJM

Enclosures

c: Ben Quinones, MDHES, w/enclosures
Jim Madden, MDHES, w/enclosures
Bill Bluck, CH2M Hill, w/enclosures
Dick Glanzman, CH2M Hill, Denver, w/enclosures
Jay Spickelmier, Asarco Denver, w/enclosures
Jon Nickel, Asarco East Helena, w/enclosures
Cynthia Leap, Gibson, Dunn & Crutcher, Denver, w/enclosures

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Table 1

RI - EP Tox Data

SUMMARY OF EP TOXICITY ANALYSES - ASARCO EAST HELENA

SITE NAME	LH-2	LH-2	LH-2	LH-2	LH-2	LH-2	LH-4	LH-4
SAMPLE DATE	10/30/87	10/30/87	10/30/87	10/30/87	10/30/87	10/30/87	10/30/87	10/30/87
LAB	ASARCO	ASARCO	ASARCO	ASARCO	ASARCO	ASARCO	ASARCO	ASARCO
DEPTH INTERVAL (FT)	16-18	14-16	10.5-12.0	8.5-10.5	6.5-8.5	4.5-6.0	6.5-8.5	8.5-10.5
PHYSICAL PARAMETERS								
PH LAB	5.9	5.7	6.2	6.1	6.5	6.8	6.6	6.2
TRACE ELEMENTS								
ARSENIC (AS) DISS	0.017	0.075	0.028	0.043	0.043	0.35	0.37	0.033
CADMIUM (CD) DISS	<0.003	<0.003	0.013	0.015	0.048	0.080	0.13	0.025
COPPER (CU) DISS	0.012	0.013	0.015	0.013	0.017	0.012	0.030	0.013
IRON (FE) DISS	0.58	0.20	0.15	0.10	0.17	2.3	0.63	0.17
LEAD (PB) DISS	0.033	0.017	0.033	0.033	0.017	0.30	0.25	0.067
MANGANESE (MN) DISS	0.36	0.40	1.8	2.7	1.5	5.7	6.0	4.1
ZINC (ZN) DISS	0.20	0.14	1.4	2.5	1.1	6.0	7.5	5.5

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All quantities in milligrams per liter unless otherwise noted. Blank line indicates parameter not tested. Output Date: 09-21-1988

IWD-6/06-01

Table 2

1312 analysis RD/RA

SUMMARY OF WATER QUALITY ANALYSES
ASEH03 - ASARCO, E.H., MT - RD/RA Design Plans

Sample Type: Sludge/Soil

SITE CODE	LH-34S	LH-37S	LH-41S	LH-42S	LH-47S	LH-49S
SAMPLE DATE	08/20/92	08/20/92	08/20/92	08/20/92	08/20/92	08/20/92
LAB	ASARCO-SLC	ASARCO-SLC	ASARCO-SLC	ASARCO-SLC	ASARCO-SLC	ASARCO-SLC
LAB NUMBER	92-5026	92-5027	92-5028	92-5029	92-5030	92-5031
REMARKS	00 M:#1312					
TYPE	M:#1312	M:#1312	M:#1312	M:#1312	M:#1312	M:#1312
SAMPLE NUMBER	EHP-9208-100	EHP-9208-101	EHP-9208-102	EHP-9208-103	EHP-9208-104	EHP-9208-105
-- PHYSICAL PARAMETERS --						
PH	8.5	7.5	7.1	7.2	6.7	6.8
-- TRACE ELEMENTS --						
ARSENIC (AS)	0.52	.69	.31	.29	.14	.56
BARIUM (BA)		<.1	.1	<.1	.12	<.1
CADMIUM (CD)	<0.05	<.05	<.05	<.05	<.05	<.05
CHROMIUM (CR)		<.1	<.1	<.1	<.1	<.1
COPPER (CU)	<.1					
LEAD (PB)	.18	<.1	<.1	<.1	<.1	<.1
MERCURY (HG)		0.0005	<0.0005	<0.0005	<0.0005	<0.0005
SELENIUM (SE)		<.1	<.1	<.1	<.1	<.1
SILVER (AG)		<.05	<.05	<.05	<.05	<.05
ZINC (ZN)	.15					

Abbreviations - TOT:Total; DIS:Dissolved; TRC:Total Recoverable; FRE:Free Cyanide; AMN:Amenable to Chlorination; EPT:EpTox; TCL:TCLP; E:Estimated, A:Anomalous Data
All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless specified as field (FLD). Blank indicates parameter not tested.

SUMMARY OF WATER QUALITY ANALYSES
ASEH03 - ASARCO, E.H., MT - RD/RA Design Plans

Sample Type: Sludge/Soil

SITE CODE	LH-54S
SAMPLE DATE	08/20/92
LAB	ASARCO-SLC
LAB NUMBER	92-5032
TYPE	M:#1312
SAMPLE NUMBER	EHP-9208-106
-- PHYSICAL PARAMETERS --	
PH	7.4
-- TRACE ELEMENTS --	
ARSENIC (AS)	.71
BARIUM (BA)	<.1
CADMIUM (CD)	<.05
CHROMIUM (CR)	<.1
LEAD (PB)	<.1
MERCURY (HG)	<0.0005
SELENIUM (SE)	<.1
SILVER (AG)	<.05

Abbreviations - TOT:Total; DIS:Dissolved; TRC:Total Recoverable; FRE:Free Cyanide; AMN:Amenable to Chlorination; EPT:EpTox; TCL:TCLP; E:Estimated, A:Anomalous Data
All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless specified as field (FLD). Blank indicates parameter not tested.

TABLE 3. SELECTED METALS* CONCENTRATIONS IN LEACHATE FROM LOWER LAKE MARSH DEPOSITS

Sample Site	Depth Below Pond Surface - ft	Leachate Concentration - mg/l As	Cd	Cu	Pb	Zn
EP Toxicity Method						
LH-34		<1.0	0.27	<0.05	2.7	19.0
LH-37		<1.0	0.44	<0.05	0.66	18.0
LH-41		<1.0	0.16	<0.05	0.41	4.4
LH-42		1.3	0.62	<0.05	1.5	19.0
LH-47		1.1	3.2	<0.05	0.5	25.0
LH-49		<1.0	0.3	<0.05	0.46	6.4
LH-54		<1.0	0.02	<0.05	0.24	5.3
TCLP						
LH-34		5.9	<0.02	<0.05	4.8	5.6
LH-37		3.8	0.02	<0.05	2.8	9.3
LH-41		2.7	0.2	<0.05	9.1	15.0
LH-42		3.6	0.52	<0.05	9.1	22.0
LH-47		3.9	3.8	<0.05	19.0	30.0
LH-49		1.9	0.92	<0.05	5.2	13.0
LH-54		2.4	0.25	<0.05	4.2	16.0
EPA Standard						
All Samples		5.0	1.0	--	5.0	--

* The RI has shown the metals of concern at the East Helena site to be arsenic, cadmium, copper, lead and zinc. There are no regulatory limits for copper and zinc in either EP Toxicity or TCLP leachate.

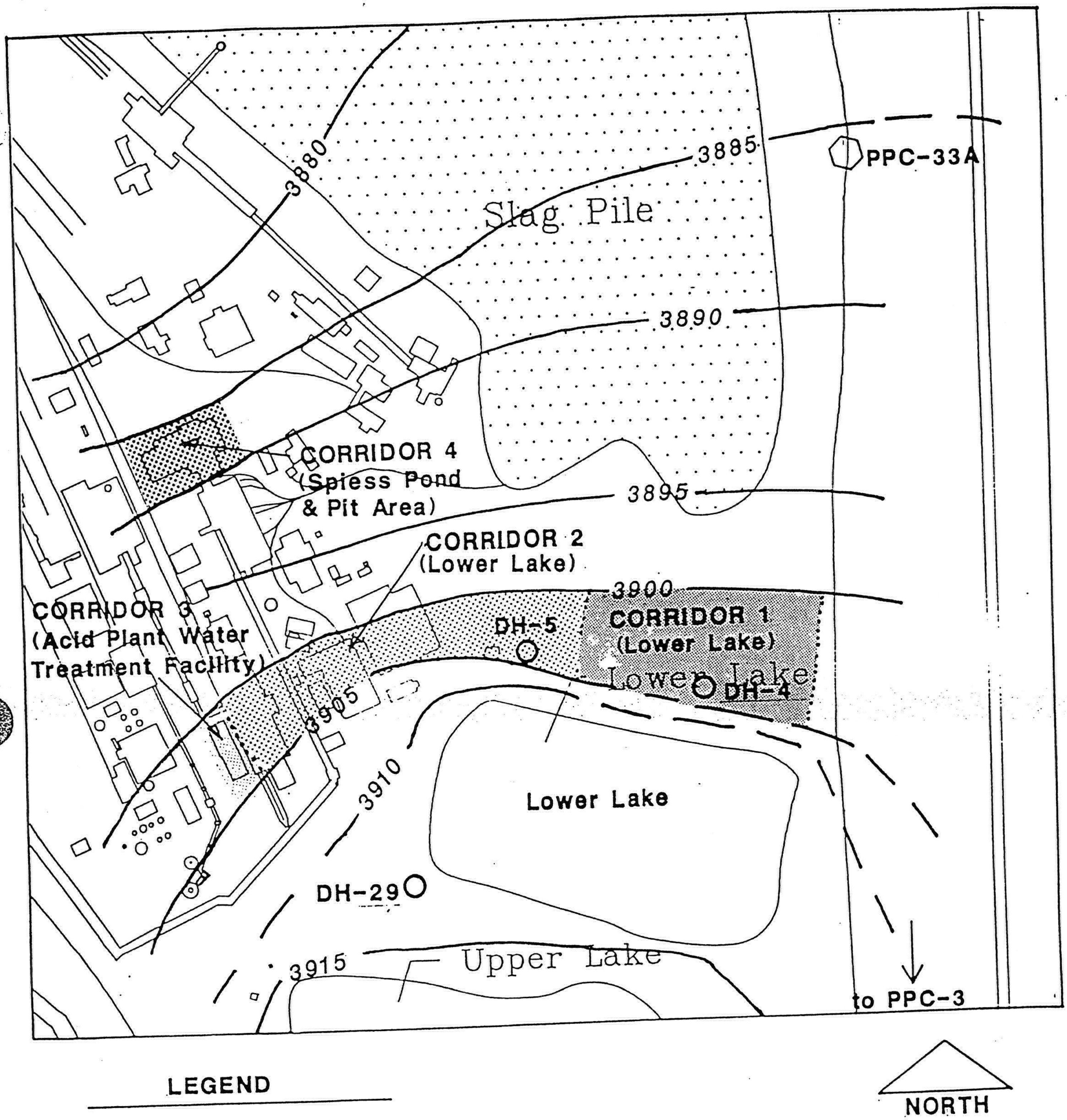

Figure 3-3: Locations of Monitoring Wells and Surface Water Sites Used For Lower Lake Seepage Estimates

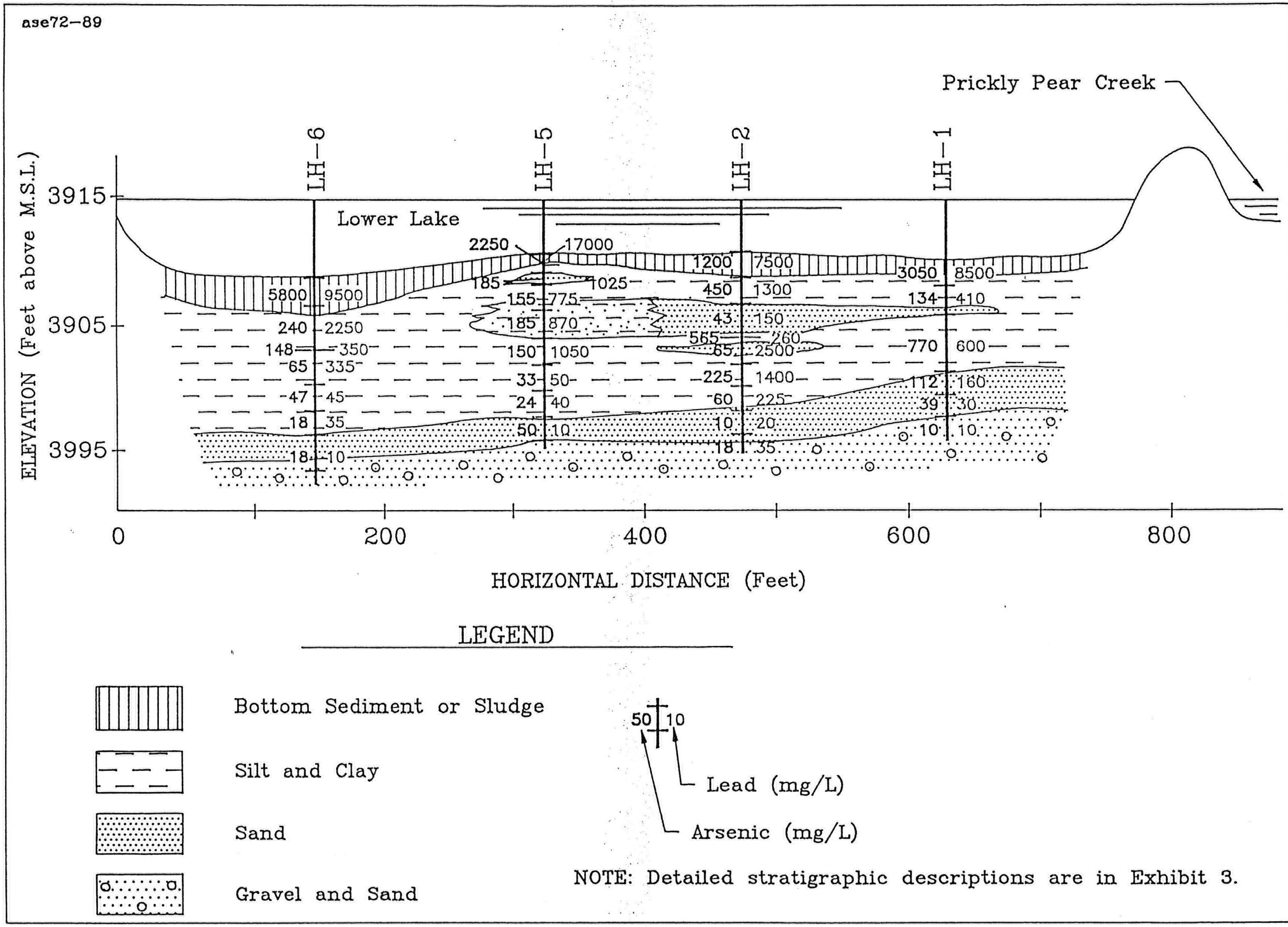

Figure 4–4–3: Chemical Profile and Stratigraphic Comparison For Lower Lake

TEST HOLE LOG

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HYDROMETRICS

HELENA, MONTANA

PROJECT: ASARCO East Helena — JOB NUMBER: — HOLE NUMBER: LH-2

STATE: Montana — COUNTY: Lewis & Clark — LOCATION: T 10 R 3W SEC. 36 TRACT ADD

SITE DESCRIPTION: Lower Lake center East Center — ELEVATION G.S.: — DATE: 10/30/87

RECORDED BY: RJM — DRILL METHOD: Casing, Drill, Washout — DRILLER: W. Crane — DRILLING COMPANY: Hydrometrics

TOTAL DEPTH: 20' — CASING TYPE AND DESCRIPTION: 3" Steel

TOTAL DEPTH CASED: 20' — WELL COMPLETION DESCRIPTION:

REMARKS: Bottom 4.5'. MP 6.0. Drove 3" steel to hold hole and obtain split spoon core samples. Bentonite around outside annulus of 3" casing as hole was driven. Bentonite pellets poured inside drive pipe 4.5 to 18' after sampling was complete and hole was abandoned.

SAMPLE	SAMPLE TYPE TIME / DATE	HAMMER BLOWS	CORE INCHES / BOTTLES KEPT	NOTES ON: WATER LEVELS, DRILLING FLUID, DRILLING RATE, WELL COMPLETION
LH-2-1S 4.5-6.9	1145 10/30	0/0/0	24/4	
LH-2-2 6.5-8	1230 10/30	0/0/0	24/4	
LH-2-3 8.5-10.5	1300 10/30	1/4/1	12/3	
LH-2-4 10.5-12	1400 10/30	1/1/1	6/3	4 Sand
LH-2-4A 12.0				4A Clay
LH-2-5 12.5-14	1430 10/30	1/1/1/1	12/3	
LH-2-6 14-16	1530 10/30	2/3/4/7	18/3	
LH-2-7 16-18	1600 10/30	4/7/15/20	24/3	
LH-2-8 19-20	1730	24/50	6/2	

DEPTH: 0, 5, 10, 15, 20

DESCRIPTION AND CLASSIFICATION

0 - 4.5	WATER
4.5 - 6.0	SILT- CLAY - OOZE, black, very soft, suspended.
6.0 - 8	CLAY, moderately soft, dark gray.
8 -10.5	SAND, moderately sorted, medium-grained to coarse-grained, rounded, predominantly quartz, loose, gray in color, occasional muscovite micas.
10.5- 11	CLAY-SILT, organic, wood chips.
11 - 12	SAND, as above.
12 - 12.5	CLAY, soft, dark gray.
12.5 - 14	SILT, sandy, organic, black, wood chips common, low density.
14 - 14.5	CLAY, as above.
14.5 - 16	SILT, organic, gray as above with wood chips; becoming sandier 15.5 to 16.5.
16 - 19	SAND, silty, fine to medium-grained, poorly sorted, rounded, predominantly quartz, dark gray, biotite common.
19 - 20	GRAVEL & COBBLES, sandy, composed of a variety of igneous and sedimentary lithologies.

TEST HOLE LOG

HYDROMETRICS — HELENA, MONTANA

PROJECT ASARCO EAST HELENA — JOB NUMBER ______ — HOLE NUMBER LH-4

STATE Montana — COUNTY Lewis & Clark — LOCATION T 10N R 3W SEC. 36 TRACT ADD

SITE DESCRIPTION Lower Lake North-east Center — ELEVATION G.S. ______ — DATE 11/3/87

RECORDED BY RJM — DRILL METHOD Casing, Drill, Washout — DRILLER W. Crane — DRILLING COMPANY Hydrometrics

TOTAL DEPTH 22.5 — CASING TYPE AND DESCRIPTION 3" Steel

TOTAL DEPTH CASED 20.5 — WELL COMPLETION DESCRIPTION ______

REMARKS Drove 3" steel to hold hole and obtain split spoon core samples. Poured bentonite around outside annulus of 3" casing as hole was driven. Bentonite pellets poured inside drive pipe 3-18 feet after sampling completed and hole was abandoned.

DEPTH	SAMPLE	SAMPLE TYPE TIME/DATE	HAMMER BLOWS	CORE INCHES / BOTTLES KEPT	NOTES ON: WATER LEVELS, DRILLING FLUID, DRILLING RATE, WELL COMPLETION	DESCRIPTION AND CLASSIFICATION
0						0 - 4.6 WATER
	LH-4-1 4.5-6.5	1045 11/3/87	0-5	24/4		4.6 - 7.5 SILT-CLAY-OOZE, partially suspended, black.
5	LH-4-2 6.5-8.5	1130	1/1/1	18/4		7.5 - 8.5 SILT, clayey, dark, looks organic, black to dark green-gray, moderately soft.
	LH-4-3 8.5-10.5	1145	0/0/0	12/3	8.75 Casing sinking into ground under its own weight.	8.5 - 8.75 THIN CLAY SEAM
10	LH-4-4 10.5-12.5	1215	0	18/4		8.75 - 10 SILT, Clayey, organic, low density wood chips (peat?); slightly sandy, dark green-gray color.
	LH-4-5 12.5-14.5	1230	0	12/4		10.5 -12.5 SILT, clay, saturated very soft.
15	LH-4-6 14.5-16.5	1400	1/2/2/2	18/4		12.5 -14.5 CLAY, silty, organic, dark gray-brown, very soft wood ships common.
	LH-4-7 16.5-18.5	1430		12/3		14.5 -16.5 CLAY, stiffer than above; grading to a sandy silt 15.5 - 16.5.
	LH-4-8 18.5-20.5	1445	8/10/10	12/3		16.5 - 19 CLAY, sandy with occasional thin (1") silty sand seams.
20	LH-4-9 20.5-22.5	1530	14/22/	6/2		19 - 20.5 SAND, poorly sorted, fine to coarse-grained, composed primarily of rounded quartz grains, green-gray color, micas common, occasional gravel pieces. Becoming coarser with depth.
						20.5- 22 GRAVEL, COBBLES AND SAND